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THE MEASUREMENT OF THE VOLUME OF CREAM ON MILK

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INTRODUCTION

With the rapid growth of cities which has taken place in the United States, particularly since 1900, there has been a correspondingly rapid development of the demand for fluid milk. The present annual fluid milk bill of this country amounts to approximately one billion dollars and it almost necessarily follows that in connection with the rapid growth of this vast business there are some unsolved problems.

A number of these problems are connected with the presence and appearance of the cream at the top of the milk bottle. This group of problems has received little study because of a lack of suitable methods for making quantitative measurements of the factors involved.

The importance of knowing the creaming conditions of the milk as delivered to the consumer has long been recognized by the milk industry, and different methods of measurement have gradually grown up in the various plants. There is, however, an almost complete lack of literature on this subject. The present publication records an attempt to bring together and study these various methods. Finding that they were not satisfactory for the study of the influence of plant operations on the volume of cream, there has been developed a simple and accurate method of measurement which has been found readily applicable under working conditions in commercial milk plants.

In working out this method and testing its applicability to milk-plant problems, extensive observations have been made in the milk plants of the Gridley Dairy Company of Milwaukee, Wis., the Sheffield Farms Company Inc. of New York City, the Detroit Creamery Company of Detroit, Mich., the Pevely Dairy Company of St. Louis, Mo., and the Bowman Dairy Company of Chicago, Ill. The opportunity thus afforded of testing the method under commercial conditions has added much to its value, and the author desires to make acknowledgment for the many courtesies extended.

While in connection with each of these milk companies there have been a number who by their criticism and suggestion have aided in this and the accompanying studies, mention is especially due Messrs. F. W. Kelly and E. S. Chrisler, of the Gridley Dairy Company, S. M. Heulings, of the Sheffield Farms Company Inc., and W. D. Dotterer, of the Bowman Dairy Company.

METHODS OF MEASURING THE VOLUME OF CREAM

The simplest method of estimating the volume of cream, and probably the one earliest used, consists of standing bottles beside each other and comparing the depth of the cream layers. Variations are discernible in this way, provided the two bottles are of the same size and shape. This is essentially the method by which the consumer decides between the product of two rival dealers and, accordingly, the method is constantly in the mind of the dealer. While there is much to be said in favor of this method, it must be admitted that it is too crude to be of much service in determining the exact volume of cream, or in tracing the factors which combine in producing the final cream layer which attracts or disappoints the prospective customer.

MEASURING FROM THE TOP OF THE BOTTLE

A simple test and one much used by milk dealers is to measure the distance from the top of the bottle to the line dividing the cream from the milk. This was the test applied by Farrington and Russell[1] in their original study of the applicability of 140°F. to the pasteurization of milk.

Since the neck of the bottle is curved, a number of devices have been employed to facilitate the measurement. One device is a measuring scale on cardboard cut to fit the neck of the bottle. The depth of the cream layer can be readily measured by applying this scale to the neck of the bottle. Another plan is to utilize the measuring instrument employed in determining the length of the human foot. When one portion of this scale is placed on the top of the bottle and the indicator brought to the line between the cream and the milk, the distance between the bottom of the cream layer and the top of the bottle can be read from the scale. In both of these measurements it is common practice to measure from the top of the bottle. This does not give the true depth of the cream layer, since the bottom of the bottle cap is approximately one-quarter inch below the top of the bottle.

Measurements of the depth of the cream layer in the neck of bottles are comparable when made in bottles of the same size and shape, having equal depressions for the bottle cap. While it would seem a simple matter for any milk company to keep a supply of uniform milk bottles, such is not the case. Comparisons of the measurements of the cream layer in bottles of different companies is further complicated by the fact that some companies are using narrower and taller bottles which increase the depth of the cream layer.

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[1]Farrington, E. H., and Russell, H. L. Pasteurization of Milk and Cream at 140°F. Wis. Agr. Exp. Sta. Ann. Rpt. 16 (1899), 129-139. 1899.

MARKING THE CREAM LINE AND DETERMINING THE VOLUME

Where measurements must be made of cream which has already risen in the bottle, probably the most accurate available method is to mark the line between the cream and the milk and determine the volume of each. If the bottle is dry on the outside the cream line may be easily marked with a colored wax pencil. The milk is then removed and the bottle filled to the mark. The volume required to fill the bottle above this mark is the volume of the cream layer. When the total volume of the bottle is also known, the percentage of the volume occupied by the cream can be readily calculated.

There are two important sources of error in these measurements. The line made by the wax pencil is fairly broad, and the cream line, particularly in milk carrying above 3.5 percent fat, occurs at a point where the neck is almost the full width of the bottle. The first source of error can be reduced by using a fine brush and ink instead of the wax pencil to mark the line separating the milk from the cream. Where the brush is not at hand, or where the bottles are moist, a file may be used. The effect of the wide portion of the bottle on the accuracy of the measurements cannot be overcome. The magnitude of the error in thus determining the amount of cream present is indicated by repeatedly measuring the volume above the mark in the same bottle.

The results of ten such successive measurements in a dozen milk bottles where the cream line was marked by a fine ink line are given in Table 1.

An inspection of Table 1 shows that in the ten successive determinations of each bottle, there were variations in the volume of cream which, among all the bottles, ranged from 4 to 12 cubic centimeters. These same variations among the different bottles, expressed in terms of cream percentage, range from 0.4 to one percent, with an average variation of 0.7 percent.

MEASURING THE DEPTH OF THE CREAM LAYER IN GLASS TUBES

It has long been the custom in making laboratory tests of the creaming ability of milk to put the milk to be tested into graduated cylinders. Cylinders with a capacity of 100 cubic centimeters have been used most frequently. When the cream has risen in such a cylinder, both the volume of the cream and its percentage of the total volume are easily determined. While this method is well suited to the laboratory study of a few samples, it is not well adapted to a large number of samples in a milk plant. Not only are such glass cylinders awkward to transport and store during the period in which the cream is rising, but the first cost is heavy and the breakage considerable.

TABLE 1.—VARIATION IN TEN SUCCESSIVE DETERMINATIONS OF THE VOLUME AND PERCENTAGE OF CREAM IN MILK BOTTLES

Bottle 1			Bottle 2			Bottle 3			Bottle 4		
Milk *cc.*	Cream *cc.*	Cream %	Milk *cc.*	Cream *cc.*	Cream %	Milk *cc.*	Cream *cc.*	Cream %	Milk *cc.*	Cream *cc.*	Cream %
820	115	12.3	815	115	12.4	815	115	12.4	815	105	11.5
821	112	12.0	815	112	12.0	813	117	12.6	815	115	12.4
821	112	12.0	812	116	12.5	815	115	12.4	817	113	12.1
823	110	11.8	813	114	12.2	810	120	12.9	812	117	12.5
821	110	11.8	813	115	12.4	812	120	12.8	815	114	12.3
818	112	12.0	810	114	12.3	809	111	12.1	816	112	12.1
821	111	11.9	815	115	12.4	816	116	12.5	814	117	12.5
821	108	11.6	812	113	12.1	814	114	12.3	813	116	12.5
820	110	11.8	816	115	12.4	816	115	12.4	818	115	12.3
823	110	11.8	818	111	11.9	813	117	12.6	818	112	12.1
Variation	*7*	*0.7*	...	*5*	*0.6*	...	*9*	*0.8*	...	*12*	*1.0*

Bottle 5			Bottle 6			Bottle 7			Bottle 8		
Milk *cc.*	Cream *cc.*	Cream %	Milk *cc.*	Cream *cc.*	Cream %	Milk *cc.*	Cream *cc.*	Cream %	Milk *cc.*	Cream *cc.*	Cream %
820	115	12.4	812	115	12.4	817	113	12.2	813	114	12.3
820	113	12.2	811	118	12.6	817	114	12.2	812	113	12.1
818	112	12.0	809	116	12.5	820	110	11.9	811	115	12.4
814	116	12.5	808	117	12.6	817	113	12.2	813	115	12.4
817	115	12.3	808	116	12.5	816	113	12.1	814	116	12.5
813	119	12.7	810	113	12.3	816	114	12.3	813	111	12.0
819	116	12.4	806	118	12.8	816	114	12.3	814	113	12.2
816	117	12.5	811	113	12.2	816	114	12.3	811	114	12.3
820	114	12.2	808	116	12.5	817	114	12.2	814	113	12.2
814	120	12.8	808	119	12.9	817	113	12.2	810	119	12.8
Variation	*8*	*0.8*	...	*6*	*0.7*	...	*4*	*0.4*	...	*8*	*0.8*

Bottle 9			Bottle 10			Bottle 11			Bottle 12		
Milk *cc.*	Cream *cc.*	Cream %	Milk *cc.*	Cream *cc.*	Cream %	Milk *cc.*	Cream *cc.*	Cream %	Milk *cc.*	Cream *cc.*	Cream %
810	117	12.6	817	115	12.4	820	110	11.8	811	116	12.5
810	113	12.2	817	116	12.3	823	109	11.7	812	116	12.5
806	119	12.9	813	117	12.6	821	109	11.7	809	118	12.6
810	115	12.5	813	117	12.6	820	110	11.8	810	115	12.5
808	115	12.5	813	117	12.6	820	110	11.8	809	116	12.5
810	118	12.7	813	117	12.6	823	107	11.5	808	120	12.9
811	116	12.5	817	116	12.3	821	109	11.7	811	119	12.8
810	115	12.5	815	116	12.4	820	108	11.6	805	123	13.1
812	116	12.6	817	117	12.5	823	118	12.5	808	119	12.8
807	117	12.6	811	120	12.8	820	110	11.8	812	118	12.6
Variation	*6*	*0.7*	...	*5*	*0.5*	...	*11*	*1.0*	...	*8*	*0.6*

Hammer and Hauser[1] modified this plan in their studies by using large test tubes (size not stated) which they filled with milk to a depth of six inches. They measured the depth of the cream layer in sixteenths of an inch and recorded it on the percentage basis, the depth of the cream layer being compared with the depth of the cream layer on a control sample of raw milk.

The use of percentages in expressing the results of these studies was unsatisfactory, largely because these percentages were based on the creaming ability of samples of raw milk. It was later found that the creaming ability of raw milk is not constant, but is influenced by a number of factors among which the period of lactation, the in-

[1]Hammer, B. W., and Hauser, A. J. The Pasteurization of Milk in the Final Package. Iowa Agr. Exp. Sta. Bul. 154. 1914.

dividuality of the cow, and the temperature at which the milk has been handled are especially important.

In his later studies of the creaming ability of milk, Hammer[1] used Nessler tubes filled to a line nine inches from the bottom. The unit used in recording the depth of the cream layer was one-sixteenth of an inch and the readings were recorded to the nearest half unit.

The Nessler tubes are accurately made and in many ways are well adapted to these tests. They are more easily stored and handled than graduated cylinders, but like them they are quite expensive, and under the conditions which must almost necessarily accompany the taking of large numbers of samples, are easily broken. Likewise, the method of holding samples of milk in ice water for twenty-four hours is not well adapted to plant practices. Accordingly, we have undertaken to develop the suggestions advanced by Hammer and Hauser so as to provide a simple and accurate method of measuring the various factors which affect the depth of the cream layer in bottled milk.

THE DEVELOPMENT OF A METHOD OF MEASUREMENT SUITED TO MILK-PLANT CONDITIONS

A successful study of the factors affecting the cream layer in a bottle of milk must be conducted largely at the milk plant. A workable method for studying these factors should combine simplicity (so as to permit the taking of a large number of samples) with a high degree of accuracy.

The first step in the present study, in developing a method of measurement, was the selection of the sample tube. Hammer and Hauser used a large test tube, filled to a depth of six inches. This was abandoned by Hammer because of the shortness of the milk column and the consequent lack of sensitiveness of the measurements. For the work herein reported there was selected a thick-walled glass test tube, without lip, one inch in diameter and ten inches long. This is a stock size and therefore not unduly expensive.

The next step was to decide upon the depth of the milk sample. Thru a desire to have this comparable with the depth of the milk in the quart bottle, it was arbitrarily placed at 216 millimeters, approximately $8\frac{1}{2}$ inches. However, as pointed out later, there are decided advantages in choosing a slightly different length.

The desired length is marked on each tube by the use of a suitable gage and a sharp file. A tin tube, slightly larger than the glass tube and of the desired length makes a good gage. The glass tube to be marked is inserted in the tin tube, the file is held against it at the edge of the tin tube, and the glass tube is rotated slightly. In this

[1]Hammer, B. W. Studies on the Creaming Ability of Milk. Iowa Agr. Exp. Sta. Research Bul. 31, 1916.

way the tube can be quickly and accurately marked. The danger of the glass tube breaking at the file mark can be practically obviated by keeping the file moistened with turpentine during the marking process.

In using these tubes to measure the creaming power of the milk before and after any treatment, it is well to fill three or more tubes from the same sample. Using the average of these readings increases the accuracy of the determination. Where the milk to be sampled is well mixed and the tubes are filled quickly from a common sample, the resulting cream layer rarely varies more than a millimeter in depth.

The temperature at which the samples are held is important. The studies of Hammer agree with commercial experience in suggesting that the temperature at which milk is held is a factor affecting the depth of the cream layer. According, samples to be compared should be kept at the same temperature.

In cold weather the milk at the receiving vat may be at 34°F., while that in the pasteurizer may be at 147°F. To bring samples to the same temperature, it is well to put the tubes at once into ice water. The samples quickly take this temperature, and they may then be removed to the bottle storage room, which has a temperature of about 40°F. It would undoubtedly result in deeper layers of cream in the tubes and more uniform results if the samples could be kept at lower and more constant temperatures. However, where the results from the tubes are to be compared with those from the bottles, there are advantages in holding both at the same temperatures.

CALCULATION OF THE VOLUME OF ROUND-BOTTOMED TUBES

One of the advantages of the Nessler tube used by Hammer was the fact that it had a flat bottom. When this flat-bottomed tube was filled with milk and later the cream layer was measured, dividing the depth of the cream layer by the depth of the milk gave the percentage of cream by volume.

With a round-bottomed tube, the percentage of cream cannot be figured in quite the same way because the rounded portion of the tube does not contain as much milk as would a flat-bottomed tube of the same length. A necessary step is to determine the length of a cylinder having the equivalent volume.

In the case of the tubes graduated at 216 mm. the following method was used. Starting at the 216-mm. mark, a distance of 200 mm. toward the bottom of the tube was indicated by a fine ink line. The tube was successively filled to the two graduations and the volumes noted, standardized burettes being used, the one for the shorter portion being graduated to 0.5 cc., the other to 1 cc.

The computation of the length of the cylinder having the same volume as the lower 16 mm. of the tube was made according to the following simple proportion:

Volume of 200-mm. portion: 200 :: volume of 16-mm. portion : x,
where x = the length of the equivalent cylinder.

In connection with studies of the creaming power of milk at various milk plants, separate consignments of tubes of these dimensions were purchased thru the regular commercial channels. Sixty-two tubes were selected as representative from four such shipments, and the measurement of their volumes according to the above method is given in Table 2.

TABLE 2.—MEASUREMENTS OF THE VOLUME OF ROUND-BOTTOMED TUBES TO DETERMINE THE LENGTH OF A CYLINDER HAVING AN EQUIVALENT VOLUME

Tube No.	16 mm. length	200 mm. length	Length of cylinder	Tube No.	16 mm. length	200 mm. length	Length of cylinder
	cc.	*cc.*	*mm.*		*cc.*	*cc.*	*mm.*
1	4.6	84.3	210.9	32	4.9	84.9	211.5
1	4.7	84.4	211.1	33	5.3	93.1	211.4
1	4.6	84.4	210.9	34	5.2	88.3	211.8
2	5.2	87.4	211.9	35	5.7	94.4	212.1
3	5.4	87.2	212.4	36	5.6	94.6	211.8
4	5.3	87.7	212.1	37	5.5	93.1	211.8
5	5.3	87.1	212.2	38	5.0	89.8	211.1
6	5.2	88.0	211.8	39	5.2	93.8	211.0
7	5.0	90.0	211.1	40	5.1	83.5	212.2
8	5.3	90.4	211.7	41	5.4	96.1	211.2
9	5.4	94.0	211.5	43	5.2	90.0	211.5
10	5.2	90.3	211.5	44	5.6	91.9	212.2
11	5.3	83.8	212.6	45	5.1	88.1	211.6
12	5.2	84.0	212.4	46	5.1	89.0	211.5
13	5.5	89.6	212.3	47	5.3	85.0	212.5
14	5.4	86.4	212.5	48	5.3	94.3	211.2
15	5.7	93.5	212.2	49	5.7	86.7	213.1
16	5.5	100.8	210.9	50	5.0	87.9	211.4
17	4.9	87.7	211.2	51	5.3	95.1	211.1
18	5.6	84.3	213.3	52	5.3	93.4	211.4
19	5.3	94.7	211.2	53	5.2	95.1	210.9
21	5.2	87.7	211.9	54	5.5	90.5	212.2
22	5.7	92.9	212.3	55	5.7	96.2	211.9
23	5.2	95.0	210.9	56	5.8	97.3	211.9
24	5.3	87.6	212.1	57	5.4	86.7	212.5
25	5.2	90.6	211.5	58	5.4	86.5	212.5
26	5.3	84.3	212.6	59	5.2	90.4	211.5
27	5.3	88.8	211.9	60	5.7	93.0	212.3
28	5.4	89.7	212.0	61	5.2	86.4	212.0
29	4.9	83.8	211.7	62	5.5	90.9	212.1
30	5.6	95.6	211.7	63	5.5	91.9	212.0
31	5.5	84.5	213.0	64	5.4	87.5	212.3
Average							212.0

NOTE.—It will be observed that triplicate readings were made of Tube No. 1; Tube No. 2 was broken.

The measurements given in Table 2 show that these sixty-two round-bottomed tubes measuring 216 mm. in length had, on the average, the same capacity as flat-bottomed tubes measuring 212 mm. (The extremes of variation were equal to tubes 1.3 mm. longer and 1.1 mm. shorter than the average.)

When the tubes are filled with milk, there ordinarily develops a cream layer of not more than 30 mm.; this gives a ratio of 1 mm. of cream to about 7 mm. of total length. Under such circumstances the above slight variation in the length of the different tubes is not sufficient to measurably affect the final reading. Accordingly, the volume of these tubes at a depth of 216 mm. may be taken as equivalent to that of a flat-bottomed tube 212 mm. long.

The object of these measurements of the tubes was to provide a basis for converting the measurement of the cream layer, given in millimeters, into percentage of cream by volume. These readings may be thus transformed by dividing the reading by 212, or by multiplying it by 0.47. The conversion of the measurement of the depth of the cream layer into percentage by volume can be even more easily done if the length of the sample tube is shortened by 12 mm., so that each millimeter in depth of cream is equivalent to 0.50 percent by volume. In this case the tubes should be filled to a depth of 204 mm., or 8 inches.

EFFECT OF DIAMETER OF TUBE ON CREAM LAYER

The Nessler tube suggested by Hammer has a diameter about one-quarter of an inch smaller than the one here proposed. The question whether this variation in diameter would have any measurable effect upon the depth of the resulting cream layer was tested in the following manner.

There were prepared fifty of the one-inch, round-bottomed tubes calibrated at a depth of 216 mm., and a like number of the flat-bottomed Nessler tubes calibrated at a depth of 212 mm. Twenty-five tubes from each set were filled with raw milk, as delivered from the barn, at a temperature above 90°F.; and the remaining twenty-five tubes from each set were filled with milk just pasteurized at 142°F. for thirty minutes. These tests were repeated on two successive days.

Each sample of milk was thoroly mixed, and small portions were transferred to a percolating jar from which tubes from each set were filled rapidly and alternately. As they were filled, the tubes were immediately placed in ice water, and when cool were transferred to a cooler kept at about 40°F. The depth of the cream layer was recorded in millimeters at the end of twenty-four hours. The results obtained from the tests of the two days are given in Table 3.

It is seen from Table 3 that the average depth of the cream layer developing on the raw milk on the first day was 28.90 mm. in the one-inch tubes and 28.94 mm. in the Nessler tubes. The corresponding depths of cream rising on the pasteurized milk were 31.20 and 31.22 mm. These averages are as close as could be expected from an average of two sets of the same tubes. On the second day the cream layer in the twenty-five one-inch tubes of raw milk averaged 33.70 mm. and in the Nessler tubes, 33.14 mm. The corresponding measurements with pasteurized milk were 31.00 mm. and 30.90 mm. If the fifty determinations with each kind of tube were averaged, the result would

TABLE 3.—COMPARISON OF DEPTH OF CREAM LAYER IN ONE-INCH AND IN NESSLER TUBES

Tube No.	Raw milk		Pasteurized milk		Tube No.	Raw milk		Pasteurized milk	
	1-inch tube	Nessler tube	1-inch tube	Nessler tube		1-inch tube	Nessler tube	1-inch tube	Nessler tube
	mm.	*mm.*	*mm.*	*mm.*		*mm.*	*mm.*	*mm.*	*mm.*
1	29.5+	30	31.5+	31.0	1	33.5	34.0	31.0	30.5
2	30.0	29.5	31.5	30.5	2	34.5–	34.0–	30.5	30.0+
3	30.0	30.0	31.0+	32.0–	3	34.5	34.0	30.5+	30.5
4	29.5	29.5+	30.5	31.5	4	34.0+	33.5	30.5	30.5+
5	29.5	30.0–	31.0+	31.5	5	34.0	33.5+	31.0	30.5
6	29.0	30.0	31.0	31.0	6	33.5+	34.0	31.0	31.0
7	29.5–	30.0–	31.5	30.0	7	34.0	32.5	31.5	31.0–
8	29.5	29.5	31.0	31.0	8	34.5	33.5	31.0+	31.5
9	29.5	29.0	31.5	31.0	9	33.5+	33.5	31.6	31.0
10	30.0–	30.0	31.0	30.5	10	34.5–	34.0	31.0	30.5+
11	29.0	28.5	31.0	31.0	11	33.0	33.0+	31.0	31.0
12	29.0	28.0	31.0	31.0	12	33.5	32.5+	31.0	31.0
13	28.5	29.0	31.0	31.0	13	34.0–	33.0	31.0	....
14	29.0	27.5	31.0	31.0	14	33.5	33.5	30.5+	31.0
15	28.0+	28.0+	31.0	30.0	15	33.5	32.5	30.5	31.0
16	28.5	28.5	31.5	32.0	16	34.0+	32.5	31.0+	31.5
17	29.0–	29.0–	31.5	31.5	17	34.0	32.5	31.5	31.0
18	28.5	28.5	31.5	31.0	18	34.0	33.0	31.5+	31.0
19	28.5	28.5	32.0	32.0	19	32.5	32.5	31.0	31.0
20	28.5	29.0	31.0	32.0	20	34.0	33.0	31.0	31.0
21	28.0+	27.5+	31.0	32.0	21	33.0–	33.0+	31.0+	31.0–
22	28.5	28.0	31.0	32.0	22	33.0	33.0	31.5+	31.0
23	28.0+	28.0	31.5	32.0	23	33.0–	33.0–	31.0+	31.0
24	27.5	29.0	31.0	31.5	24	33.0	33.0	31.5	31.0–
25	28.0	29.0	31.5	31.5	25	34.0–	33.0	31.0	31.0+
Aver.	28.90	28.94	31.20	31.22	Aver..	33.70	33.14	31.00	30.90

be 30.05 mm. with the one-inch tubes and 30.09 with the Nessler tubes. These results make it evident that when cylinders differing in diameter from three-fourths of an inch to one inch are filled with milk to the same depth and held at the same temperature, they will later develop equal layers of cream.

The results obtained from the twenty-five tubes filled from each sample of milk furnish evidence as to the variation to be expected when using this method of measuring the depth of the cream layer. However, in considering these results it should be remembered that in filling twenty-five tubes there is the added problem of keeping the fat in the original sample uniformly distributed. In testing the influence of the two kinds of tubes this disturbing factor was largely eliminated by filling the two kinds of tubes alternately, but in the inspection of the results with either tube its influence is evident. In the case of the one-inch tubes, the cream layer on the raw milk varied on the first day from 27.5 to 30 mm., and on the second day from 32.5 to 34.5 mm. With the samples of pasteurized milk, the variation was from 30.5 to 32 mm. on the first day and from 30.5 to 31.5+ mm. on the second day. The variations in the case of the Nessler tubes were essentially the same. Where but three sample tubes were filled from a single sample and the time element was thus avoided, the variation among the three tubes was rarely more than one mm.

COMPARISON OF VARIOUS METHODS OF MEASURING THE CREAMING ABILITY OF MILK

A comparison of the results obtained by the different methods for measuring the volume of cream is made possible by applying them simultaneously to the same milk. Accordingly, successive bottles of milk were taken as they came from the bottler and were immediately placed in the cooler for about twenty hours. The depth of the cream layer on each bottle was then measured, the cream line marked, and the volume of cream and the percentage of cream in each bottle determined. As these bottles were selected at the bottler, other bottles were also taken, and from them test tubes were filled. The tubes of milk were cooled in ice water and placed in the cooler with the bottles, for about twenty hours. The depth of cream in these tubes and the percentage of cream which these readings represented were also noted. The results of these comparable observations are given in Table 4.

The data in Table 4 present comparable results obtained by three different methods of measurement and offer some information as to the variation to be expected with each method.

In the samples taken June 25 and 26, three successive bottles as they came from the filler were reserved for measurement, and three tubes were filled with milk from a fourth bottle. Variations in the measurements of the depth of cream in each of these sets of three bottles varied among the different sets from zero to $\frac{2}{16}$ of an inch, with an average variation of slightly more than $\frac{1}{16}$ of an inch. In the determination of the percentages of cream in these sets there were variations ranging from 0.21 to 0.92 percent and averaging 0.47 percent.

Since the measurements of the volume of cream in the bottles and the measurements in the tubes are both expressed in percentages of cream by volume, they offer an opportunity for comparison. In making this comparison it is necessary to omit the results from the first three bottles of June 25 and the last three bottles of June 26 because no comparable readings were made in tubes. A comparison of the percentages for the same groups of bottles obtained by the two methods shows that ordinarily the percentage obtained by the tube method is slightly lower than that obtained by bottle measurement. Likewise, the averages of the two groups of comparable determinations show that the results obtained by the tube method are on the whole about one-third of a percent lower than those obtained by bottle measurement.

In Table 4 the data are presented in the order in which the samples were taken. Among the methods compared, the one most widely used in milk plants is that of measuring the depth of cream from the

TABLE 4.—COMPARISON OF DIFFERENT METHODS OF CREAM MEASUREMENT

Date 1921	Sample No.	Cream depth	Measured in the bottle			Measured in tube	
			Bottle volume	Cream volume	Cream	Cream depth	Cream
		in.	*cc.*	*cc.*	%	*mm.*	%
6/16	1	3	941	121	12.85	27.0	12.74
	2	3 2/16	946	121	12.79	27.0	12.74
	3	3	942	121	12.84	25.5	12.02
	4	3 1/16	946	120	12.68	26.0	12.26
	5	2 14/16	940	110	11.70	25.0	11.79
	6	3 1/16	943	122	12.94	27.0	12.74
	7	3	937	125	13.34	25.5	12.03
6/17	1	3	939	132	14.06	27.5	12.98
	2	3 2/16	932	121	12.98	26.0	12.26
	3	3	941	130	13.82	26.0	12.26
	4	2 15/16	944	108	11.14	23.0	10.85
	5	2 13/16	938	98	10.45	22.0	10.38
	6	2 15/16	929	105	11.18	25.0	11.79
6/18	1	2 15/16	931	116	12.46	26.5	12.50
	2	2 15/16	933	112	12.00	26.0	12.26
	3	2 15/16	936	109	11.65	25.0	11.79
	4	2 14/16	936	108	11.54	24.0	11.32
	5	2 14/16	940	103	10.96	23.5	11.09
6/24	1	3 2/16	934	124	13.28	27.5	12.98
	2	3 1/16	933	122	13.08	27.0	12.74
	3	3 3/16	938	125	13.33	27.0	12.74
	4	3 1/16	941	120	12.75	25.5	12.03
	5	3 1/16	938	111	11.83	25.5	12.03
6/25	1.1	3 1/16	937	119	12.70		
	1.2	3 2/16	935	122	13.06		
	1.3	3 1/16	939	123	13.10		
	2.1	3 3/16	934	124	13.28		
	2.2	3 2/16	937	122	13.02		
	2.3	3 1/16	940	121	13.01		
	2.4	....	...	...	.....	26.0	12.26
	3.1	3 1/16	943	127	13.45		
	3.2	3	930	120	12.90		
	3.3	3 1/16	934	122	13.06		
	3.4	....	...	...	.....	26.0	12.26
	4.1	3	935	115	12.28		
	4.2	3	932	113	12.12		
	4.3	3 2/16	933	115	12.33		
	4.4	....	...	...	.....	25.0	11.79
	5.1	2 15/16	940	111	11.81		
	5.2	3	940	109	11.60		
	5.3	3	938	110	11.73		
	5.4	....	...	...	.....	24.5	11.56
6/26	1.1	3 3/16	939	129	13.74		
	1.2	3 3/16	939	129	13.74		
	1.3	3 3/16	940	138	14.66		
	1.4	....	...	...	.....	29.0	13.68
	2.1	3 3/16	928	121	12.90		
	2.2	3 2/16	940	135	14.36		
	2.3	3 3/16	941	125	13.28		
	2.4	....	...	...	.....	28.5	13.45
	3.1	3 1/16	940	123	13.08		
	3.2	3	942	121	12.85		
	3.3	3 2/16	941	128	13.60		
	3.4	....	...	...	.....	26.0	12.26
	4.1	3 1/16	940	119	12.66		
	4.2	3 1/16	940	120	12.77		
	4.3	3 1/16	942	116	12.31		
Average (omitting first three bottles of 6/25 and last three of 6/26					12.48		12.14

top of the bottle. In order to better present this part of the data, Table 5 is presented.

TABLE 5.—MEASUREMENT OF CREAM LAYER IN BOTTLES: VARIATION IN PERCENTAGE MEASUREMENTS OF VOLUME WHEN CREAM LAYERS ARE THE SAME DEPTH

Depth of cream	Volume of cream		Variation
inches	%		%
2 13/16	10.45		....
2 14/16	10.96 11.54 11.70		0.74
2 15/16	11.14 11.18 11.65	11.81 12.00 12.46	1.32
3	11.60 11.73 12.12 12.28 12.84 12.85	12.85 12.90 13.34 13.82 14.06	2.46
3 1/16	11.83 12.31 12.66 12.68 12.70 12.75 12.77	12.94 13.06 13.08 13.08 13.10 13.10 14.45	2.62
3 2/16	12.33 12.79 12.98 13.02	13.05 13.28 13.60 14.36	2.03
3 3/16	12.90 13.28 13.28 13.33	13.74 13.74 14.66	1.76

Considerable variation between the results of measurements of the depth of the cream layer and determinations of the percentage of cream by volume is evident. The extent of this variation increases with an increase in the number of observations, and a still larger number of observations is needed to determine its probable range. In the case of eleven bottles on which the cream layer measured 3 inches, the range of variation was 2.46 percent; and in the case of fourteen bottles on which it measured $3\frac{1}{16}$ inches the range was 2.46 percent.

The cause of these wide variations is a matter of interest. Where the cream line is distinct there is little difficulty in accurately measuring its depth, and variations in the results of such measurements are to be expected only where the depth is approximately midway between sixteenths of an inch. The data presented in Table 1 suggest that the variation due to this cause should rarely exceed one percent with a single bottle. The much wider variations presented in Table 5 are undoubtedly due to variations in the shape of the milk bottles.

Uncertainties in the results of measurements of the depth of the cream layer are further shown by the fact that one bottle having a 3-inch cream layer contained less cream than another with a $2^{14}/_{16}$-inch cream layer. Again another with a 3-inch cream layer contained more cream than a number of other bottles with cream layers measuring $3^{3}/_{16}$ inches.

When such wide variations are found in the bottles of a single milk company which has exerted itself to maintain a uniform stock, it is evident that the variations between the bottles of different companies is much wider.

The consumer now uses the depth of the cream layer as an index of the relative richness of the milk of two rival dealers. Where the size and shape of the bottles are similar and the milk has been pasteurized at the same temperature, it is probable that the bottle with the deeper cream layer contains the richer milk. However, the data here presented make it evident that even under such conditions one cannot be certain which bottle contains the richer milk until the difference in the depth of the cream layer amounts to at least one-quarter of an inch. Where the comparison includes a bottle designed to extend the cream layer, even this great a difference in depth of cream cannot be taken as an indication of a larger volume of cream.

The interests of good business will be furthered by furnishing the consumer with a more accurate method of judging richness than that offered by the depth of the cream layer in the milk bottle. The practice already operative in some cities of stating the fat content of the milk on the bottle cap is a step in this direction.

The housewife, however, not only desires a rich milk but she desires the cream to be available. By using the method of measurement outlined in this publication, the milk dealer can measure accurately the effect upon the cream layer of each step in his plant processes, and in the light of such knowledge he can then so modify his practices as to put almost the entire fat content in the top of the bottle.

SUMMARY

There are wide differences of opinion as to the factors which influence the volume of cream in the milk bottle. This conflict of opinion is largely unsupported by direct evidence, and this lack of evidence has been due primarily to the lack of a method for measuring the volume of cream, which is both accurate and readily applicable under milk-plant conditions.

The method of measurement herein described consists of filling round-bottomed test tubes, one-inch in diameter, to a depth of 204 millimeters (8 inches) with the milk to be tested. These tubes of milk are immediately cooled in ice water; and when cool, are held at 40° F. for approximately twenty-four hours. The depth of the resulting cream layer is measured in millimeters, and each millimeter of cream represents 0.5 percent of cream by volume.

The volume of cream as determined in this way agrees closely with the volume of cream developed in milk bottles under similar temperature conditions.

This method has been extensively tested in milk plants and its advantage lies in the fact that by its use a large number of samples may be collected during a single day, the samples stored compactly, and the determinations made quickly, accurately, and quantitatively.